Automatic extraction of the low-motion phases of the heart

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Introduction

The resulting image quality in cardiovascular MRI and especially in the imaging of the cardiac vasculature significantly depends on the correct identification of the optimal cardiac phase point yielding minimal residual cardiac motion during data acquisition. In current clinical practise the low motion phases best suited for data acquisition are identified manually from a single slice multi-phase cine sequence acquired directly prior to the volume acquisition. The automatic extraction of the low motion phases is desirable for enabling a user-independent selection of optimal gating windows [1], which can efficiently be evaluated in multiple slices [2] for providing optimal gating window parameters derived from the entire volume of the heart. An automatic detection algorithm for the determination of the spatially dependant optimal gating window parameters is presented. The approach is based on the comparison of the similarity between images obtained in successive cardiac phases at multiple locations along the long axis of the heart.

Methods

Short-axis, multi-phase, multi-slice functional data of the heart was obtained at a 1.5T whole-body system (Philips Intera). Ten to thirteen slices were arranged along the long axis of the heart covering the entire LV in apical to basal direction. Image resolution was as 1.4x1.4x10mm³ with 10mm spacing between neighbouring slices. All data were acquired applying a conventional steady-state-free-precision sequence (ssfp) with TE/TR = 1.9/3.8ms and 55° excitation angle. The data required for the reconstruction of all cardiac phases of a single slice were acquired in a single breathhold. Thirty-two cardiac phases, equally spread over the cardiac cycle, were reconstructed by means of a retrospective gating technique. A cardiac motion index M(z, Φ_i) was extracted for each cardiac phase Φ_i and slice position z by means of similarity measures between images obtained in successive cardiac phases. Similarity measures used were either based on the normalized image differences (a) or the cross-correlation (b), according to:

a) $M(z,\Phi_i)=\frac{\sum_{x,y} abs(A_z(x,y)-B_z(x,y))}{\max_{x,y}(abs(A_z(x,y)-B_z(x,y)))}$ b) $M(z,\Phi_i)=1-\max\left(\frac{FT(A_z)FT(B_z)^T}{std(A)std(B)n_x n_y}\right)$ with A_z and B_z being the images obtained at slice position z in cardiac phase Φ_i and Φ_{i+1} The optimal phase point $\Phi_{opt}(z)$ for location *z* was defined as $\Phi_{opt}(z)=\min_{\Phi}(M(z,\Phi_i))$. The start and end-point of the low-motion phase are determined by the start and end point of the longest contiguous interval around $\Phi_{opt}(z)$ with $\Phi(z)<0.05\,\Phi_{\max}(z)$.The method was tested in 10 patient data sets and the automatically derived values were compared to the optimal phase point extracted manually by an experienced reader.

Results

An example of the spatially resolved motion map is given in Figure 1. In the graph, phases of low correlation (high motion) are color-coded red and phases with high correlation (low motion) are color-coded blue. The two resting phases and the contraction and relaxation phases can be clearly distinguished. The solid yellow line indicates the path of minimal motion and the dashed lines indicate the start and end point of the minimal motion phases. Please note that the position as well as the width varies with the z-position. The phases of high and low motion could be clearly distinguished in all patient data sets. In 2 cases, a variation of optimal gating window position of more than one cardiac phase steps was observed along the long axes. Comparison of the automatically and manually derived optimal phase point position and low motion period revealed a high degree of concordance.

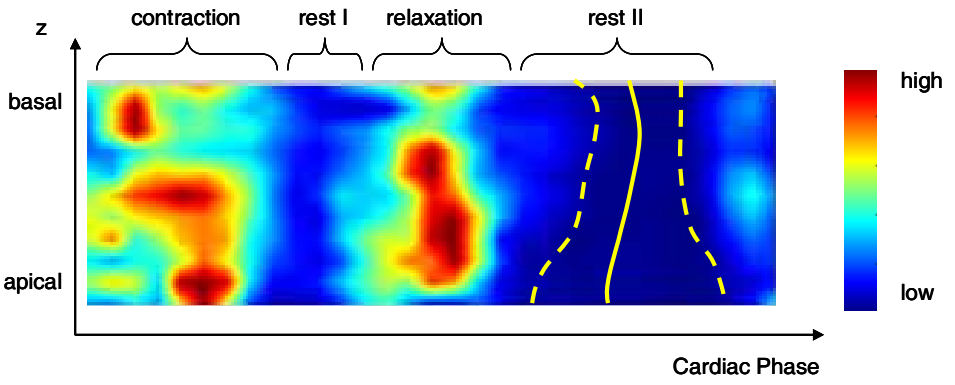

Figure 1: Map of the motion index M, depending on the position z along the long-axis of the heart and the cardiac phase.

Discussion

Automatic extraction of the spatially resolved minimal motion phases of the heart over the cardiac cycle along the long axes of the heart appears feasible. The observed slight variation of optimal phase points depending on the position along the heart axis suggests using different gating delays for different regions of the heart. The possible improvement in image quality applying spatially-dependent gating windows has to be shown in further studies.

References

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